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Nonwoven mat, method for production thereof and fibre composite

The invention relates to a nonwoven mat as half-stuff which contains a high performance thermoplast as melt fibre and a reinforcing fibre, and also a method for producing a nonwoven mat of this type and fibre composites produced from the nonwoven mat.

The production of nonwovens by the wet method in typical modes of operation derived from paper production is known in the state of the art. In "Nonwovens", Viley-VCH, Viley-VCH Press, Weinheim 2000, from page 235 ff., a method of this type is described. The method is thereby implemented such that the fibres are dispersed in water, then a continuous nonwoven formation is effected on a wire belt by filtration and subsequently compaction, drying and rolling-up of the formed nonwoven web is undertaken.

Methods of this type are used essentially for paper production, such as e.g. synthetic fibre paper, teabag paper, air filter paper or also cigarette covering papers.

The method of the state of the art was hence applied only for the production of special papers or special technical nonwovens as end product.

Moulded articles are also known from the state of the art which were formed from melt fibres and a reinforcing fibre. A moulded article is disclosed in EP 0 774 343 A1 which comprises a core layer and a cover layer, the core layer being formed from melt fibres and a reinforcing fibre. It has however been shown that this moulded article is suitable only for the purpose of use mentioned in the above European application. The moulded article according to EP 0 774 343 A1 has in fact inadequate properties with respect to density and strength and is hence limited in its applicability.

It is therefore the object of the present invention to provide a novel nonwoven mat which is suitable as half-stuff for producing fibre composites with high density. Furthermore, it is an object of the present invention to indicate a method in this respect for producing a nonwoven mat of this type. The method is intended furthermore to have great variability with respect to the usable components and the properties which can be achieved therewith.

The object is achieved with respect to the nonwoven mat by the characterising features of claim 1, with respect to the method for producing the nonwoven mat by the features of patent claim 22 and with respect to the fibre composite by the features of patent claim 30. The sub-claims reveal advantageous developments.

According to the present invention, a nonwoven mat is hence proposed which contains at least one first fibre made of a high performance thermoplast as melt fibre and at least one second fibre as reinforcing fibre made of a high performance material. The individual fibres are fixed in the nonwoven mat by means of a binder. In the case of the subject of the present invention, it is essential that, in the nonwoven mat, the melt fibres have a smaller fibre length than the reinforcing fibre. The melt fibre is thereby contained with a weight proportion of 30 to 90% by weight and the reinforcing fibre in the nonwoven mat with a weight proportion of 10 to 70% by weight.

As a result of the fact that the fibre length of the melt fibre is smaller than that of the reinforcing fibre, a homogeneous mixing of the two types of fibre is achieved so that, in the case of subsequent further processing of the half-stuff, a uniform homogeneous distribution of the reinforcing fibre in the fibre composite is then achieved. The fibre orientation of the fibres in the layer can be isotropic and/or anisotropic.

In the case of the method according to the invention, it is therefore preferred if the melt fibre is 0.1 mm to 30 mm, preferably 2 mm to 6 mm and very particularly preferred 2.5 mm to 3 mm. Furthermore, it should be ensured that as uniform a fibre length as possible is present so that as homogeneous a distribution as possible of the melt fibre in the nonwoven mat can also be achieved. The reinforcing fibre made of the high performance material can likewise have a length of 0.1 mm to 30 mm but, as is defined by patent claim 1, is respectively always larger than the melt fibre. A suitable fibre length for the reinforcing fibres is 6 mm to 18 mm, particularly preferred 6 mm to 12 mm. In the case of the reinforcing fibre, it should also be ensured that as uniform a fibre length as possible is present.

From the point of view of material, the invention includes all the fibres known in the state of the art with respect to the melt fibre, said fibres being producible from a high performance thermoplast. Examples of fibres of this type are fibres made of polyether etherketone (PEEK), poly-p-phenylene sulphide (PPS), polyether imide (PEI) or polyether sulphone (PES) and/or mixtures thereof.

In the case of the reinforcing fibres those which are producible from high performance materials can be used. Examples of these are fibres made of polybenzoxazole (PBO), polyimide (PI), polybenzimidazole (PBI), metal fibres, glass fibres, aramide fibres, carbon fibres, ceramic fibres, natural fibres and/or mixtures thereof.

As already explained above, the nonwoven mat according to the invention is constructed such that the individual fibres are fixed together by means of a binder. The fibres themselves are thereby still present just as they were at the outset and are bonded to each other by the binder merely at the intersection points or at the contact points. This construction of the nonwoven mat is important since, for the composite material to be produced subsequently, splaying apart of the reinforcing fibres and/or non-homogeneous mixture must be avoided.

The binder itself can thereby be a binder which acts physically and/or by glueing.

If a physically acting binder is used, a binding effect is achieved by cramping/hooking of the fibres by the binder. For this reason, filaments, fibrids and/or fibrous binders are suitable as binders.

The advantage of a binder of this type resides in the fact that essentially it does not have to be removed from the system during the subsequent further processing under pressure and temperature but instead stays retained in the finished material and thus the properties of the material can also be specifically controlled.

The melt-bonding binders (Thermobonding) are chosen such that their melting point is below that of the melt fibre and hence a bonding effect is thus produced.

In the case of the binders, those can be used according to the present invention based on polyvinyl alcohol (PVA), polyvinyl acetate (PVAC), ethylene vinyl acetate (EVA), polyacrylate, polyurethane (PUR), resins, in particular for example melamine resin or phenol resin, polyolefins such as polyethylene (PE), polypropylene (PP), aromatic polyamides (aramides) and copolymers thereof.

The binder can be a dispersion or have the form of filaments, fibrids or have a fibre-like character. In the case of a binder of this type, the geometry can vary with respect to the length/width/height ratio for each individual parameter in the ratio relative to each other in the range of 1 : 1 to 1 : 100,000.

The nonwoven mat according to the invention can of course also contain additives in addition. Those additives can be used in order to influence the properties of the nonwoven mat and hence also subsequently those of the fibre composite produced with the nonwoven mat. According to the present invention, additives can therefore be used which affect the properties, such as electrical conductivity, heat conductivity, frictional behaviour, temperature resistance, impact strength, strength or abrasion resistance. Additives of this type can be used for example in the form of

fibres, filaments, fibrids or pulps. The additives can be PTFE fibres or powder, PI fibres, aramide fibres, carbon fibres or metallic and/or ceramic and also organic powder. Nanoscale C-fibres are particularly suitable. The nonwoven mat can therefore also function as a functional layer.

It is now essential that the nonwoven mat according to the invention has a very low basis weight. Furthermore, the high uniformity of the sheet material in the longitudinal and transverse direction with respect to the thickness is characteristic. According to the reinforcing fibres and melt fibres which are used and the weight proportions thereof, the nonwoven mat can have a basis weight of 8 to 400 g/m^2, preferably 50 to 150 g/m^2 and a density of 30 to 500 kg/m^3, preferably 100 to 200 kg/m^3. The nonwoven mat according to the invention is preferably 0.1 mm to 4 mm, particularly preferred 0.5 mm to 2 mm thick. The low basis weight makes it possible for very thin moulded articles to be produced in the subsequent compaction process.

The nonwoven mat according to the invention can furthermore be constructed also such that a flat substrate is applied on at least one outer side of the nonwoven mat. This has the advantage that this flat substrate can be configured for example also as a functional layer and, in the further processing procedure, i.e. when the half-stuff is processed into an end product, this functional layer can then also take over specific functions, such as conductivity or also a special glueing function. The flat substrate can thereby be configured in the form of a woven fabric, plaited fabric, paper or nonwoven. A further alternative of the nonwoven mat according to the invention provides that at least two nonwoven mats are disposed one above the other, i.e. that a further nonwoven mat serves as flat substrate so that then a composite of two nonwoven mats is present.

The invention relates furthermore to a method for producing a nonwoven mat as described above. The method according to the invention provides that the melt fibre and the reinforcing fibre are dispersed in a dispersion agent, preferably water, and that a continuous nonwoven formation is effected on a wire belt by filtration and subsequently compaction and drying of the nonwoven is effected. The binder can thereby be added during the dispersion step and/or during the nonwoven formation.

As is known per se from the state of the art already, the method according to the invention is implemented with a diagonally running wire.

It is preferable furthermore if the binder is added in the form of a dispersion. The addition of the binder can thereby be effected both during the dispersion step and during the nonwoven formation.

Equally, it is possible to add the additives during the dispersion step or during the nonwoven formation.

It is an advantage of the method according to the invention that the basis weight, the density and thickness of the nonwoven can be controlled by the material composition of the dispersion and/or the supply speed of the dispersion towards the diagonal wire and/or the transport speed thereof. It is consequently possible now to produce nonwoven mats with a basis weight, as described above, of 8 to 400 g/m^2 and a density of 30 to 500 kg/m^3. It is essential, in the case of the method according to the invention, that a homogeneous mixture is made available in the form of a dispersion of the educts so that a homogeneous distribution of the types of fibre, melt fibre and reinforcing fibre is then achieved during accumulation of this dispersion on the wire. In the case of the method according to the invention, it was particularly surprising that the nonwoven mat produced with the fibres described above has excellent

stability. Consequently, it is now possible to process this nonwoven mat in further processing steps into an end product.

In order to produce a nonwoven mat which also has a flat substrate on at least one outer side, it is provided that the nonwoven formation is effected with sheet materials placed on the diagonal wire. These sheet materials can be a plaited fabric, woven fabric or a nonwoven.

The invention relates furthermore also to a fibre composite according to the features of patent claim 30.

The fibre composite of the present invention is distinguished in particular in that the reinforcing fibre with a weight proportion of 30 to 90% by weight relative to the weight proportion of the composite material is distributed homogeneously in the material. The orientation of the fibre in the matrix of the fibre composite can be isotropic and/or anisotropic. The fibre length of the fibres in the fibre composite is thereby 0.1 mm to 30 mm, preferably 6 mm to 18 mm, very particularly preferred 6 mm to 12 mm. The fibres are thereby selected from fibres made of high performance materials, as are known in the state of the art. Reference is made in this respect to the description of the nonwoven mat.

The matrix of the fibre composite according to the invention is formed preferably from a high performance thermoplast. From the point of view of materials, the high performance thermoplasts can be used, as likewise described above already in the case of the nonwoven mat.

It is now essential that the fibre composite according to the present invention has a density which is between 0.25 and 6 g/cm^3. It was shown that the density which can be achieved with the fibre composites according to the invention is between 30 and 100% of the maximum

achievable density which is calculated from the density of the individual initial materials, i.e. the reinforcing fibres and the matrix. As a result, for the first time a high performance material is now available which is comparable in its properties to metallic materials. The material could hence also be described as plastic sheet metal.

The fibre composite according to the present invention is present preferably in the form of a flat structure but can of course then be shaped into three-dimensional structures. The thickness of the fibre composite in the form of the flat structure is preferably between 0.01 to 0.2 mm.

The fibre composite according to the invention can furthermore have another functional layer. This functional layer is present at least on one side of the fibre composite according to the invention.

The fibre composite according to the invention can be produced preferably by compaction of at least one nonwoven mat in a heated tool according to at least one of the claims 1 to 20. Suitable pressures in this respect are 0.05 - 15 N/mm^2. The density of the fibre composite to be produced can be adjusted according to the pressure applied and the reinforcing fibres used.

The invention is explained in more detail subsequently with reference to production examples and Figures.

Fig. 1 thereby shows the diagrammatic representation of a device for producing the nonwoven mat;

Fig. 2 and 3 show electron microscopic images of a fibre composite according to the invention.

Example 1: production example of a nonwoven mat

A nonwoven was produced by way of example under VP00054.

PPS cut length 3 mm	81% by weight
carbon fibre cut length 6 mm	19% by weight
relative to:	
binding fibre PVA 4 mm	10% by weight

Basis weight:	128 g/m^2
Thickness:	0.95 mm
Density:	0.135 g/cm^3

Example 2: production example for fibre composite

From this nonwoven, consolidated fibre composites were produced:

Single-layer compaction

Compaction temperature:	350°C
Surface pressure:	3.3 N/mm^2
Thickness:	110 µm
Density:	1.17 g/cm^3

Fig. 1 shows the diagrammatic representation of a diagonal wire unit as was used for producing the nonwoven mat according to the invention. The device 1 thereby comprises a diagonally running wire 2 and also a horizontal supply mechanism 3 with which the dispersion of the melt fibres and the reinforcing fibres is supplied to the diagonally running wire 2. The diagonally running wire 2 is thereby configured such that dewatering is possible. A corresponding collection container 4 is provided

for this purpose. A corresponding device 5 which is adjustable is disposed for controlled thickness adjustment in order to produce the thickness of the nonwoven. The dispersion comprising the fibres, as explained above, is guided over the horizontal channel 3 to a revolving belt which is directed via rollers 6. After supply of the dispersion, the nonwoven is guided over a drying mechanism 7 in order to ensure binding of the individual fibres with the binder. The thus produced nonwoven mat is then removed.

Fig. 2 and 3 show electron microscopic images of a fibre composite according to the invention. The fibre composite according to Fig. 2 and 3 is a composite material which was produced from a nonwoven mat comprising glass fibres as reinforcing fibres and PPS fibres as melt fibres. As the electron microscopic images of Fig. 2 and 3 show, the reinforcing fibre 9 is distributed homogeneously in the thermoplast matrix. It also emerges from Fig. 2 and 3 that the corresponding fibres are present virtually unchanged, in particular not shortened. This contributes decisively to the increase in the modulus of elasticity and in particular to the tensile strength of the material in comparison to purely unreinforced thermoplast films.